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I. INTRODUCTION

Light-valve-projector technology offers potential solutions to high-brightness and high-resolution large-screen display requirements. Previously developed liquid-crystal light valves are capable of real-time projection imaging at video rates.[1-3] These light valves have the potential of achieving resolution greater than 2,000 TV lines and photosensitivity less than 50 $\mu W/cm^2$. However, the current use of these light valves prevents their full utilization potential as an ultra-high resolution device because they are limited by the resolution of the cathode ray tube (CRT) used to photoactivate the liquid-crystal light valve (LCLV).

The goal of this work is to develop an ultra-high resolution (greater than 2,000 TV lines) laser-addressed LCLV imaging system operating at video rates for real-time applications to large-area projection displays. The approach is to identify and develop state-of-the-art high-speed laser-beam scanning techniques with resolution greater than 1,000 TV lines at video rates to photoactivate the LCLV. With this high-resolution objective, high-speed mechanical scanners, such as multifaceted-spinning polygon mirrors, have several disadvantages when operated at TV rates. This display system employs the technique of laser addressing to photoactivate the LCLV.

To exploit the high-resolution and relatively high-speed display capability of the photoactivated LCLV, and to develop a more compact and rugged raster scanner, a 525-line video-rate laser-addressed LCLV, was developed initially.[4] This first prototype, conforming to an EIA RS-170 TV Standard, included a compact all-solid-state laser raster scanner (LRS) using acousto-optic (AO) components to modulate and deflect the laser beam. The high-speed AO horizontal laser beam deflector employed in this LRS design operated in a conventional way. However, in order to achieve resolution higher than 1,000 TV lines using AO devices, the acoustic traveling wave lens (ATWL)[5,7] approach was employed.

This paper describes the basic design parameters of the LRS (using all AO devices to modulate and deflect the laser beam), the characteristics of the major components, and the performance of the prototype display system.

II. CHIRP SCANNER DESCRIPTION

The primary constraint upon the design of the LRS was the desire to use the RS-343-A input signal format. As shown in Table I, this defines the total horizontal line time T to be 31 μsec, of which 7 μsec is allotted to blanking during horizontal flyback.

If standard AOBD is used to produce the horizontal scan, the number of resolvable spots N for such a device can be approximated by[6]

$$N = \tau \Delta f (T - \tau)/T$$

where τ is the time for the acoustic wave to transit the optical beam, Δf is the bandwidth of the frequency sweep, and T is the time during which frequency sweep occurs.

With RS-343-A, only 7 μsec are available to fully develop the diffracted beam, $t = 7$ μsec. Likewise, frequency sweep can occur only over the total line time, giving

$$T = 31 \ \mu\text{sec}.$$

The requirement for $N = 1280$ resolvable spots/line, therefore, indicates the need for a frequency bandwidth of $f = 236$ MHz. Combining this with the necessity of preventing overlap between the first and second diffraction orders, results in the need to operate in a frequency range of 236–472 MHz. Design of a TeO scanner capable of maintaining uniform Bragg diffraction efficiency across this frequency range is difficult.

To avoid this difficulty, a traveling-lens-type AO scanner was used. This technique utilizes the principle that an acoustic chirp (frequency sweep) causes light to converge or diverge like a cylindrical lens. If a short-duration chirp is produced and allowed to propagate across an illuminated aperture, the effect is to scan a focused spot along a line.

TABLE I. LRS Characteristics.

Raster format	1075 lines
Active line time	24 μsec
Horizontal blanking time	7 μsec
Total horizontal line time	31 μsec
Frame rate	30 Hz (interlaced 2:1)
Timing and levels	RS-343-A EIA TV Standard

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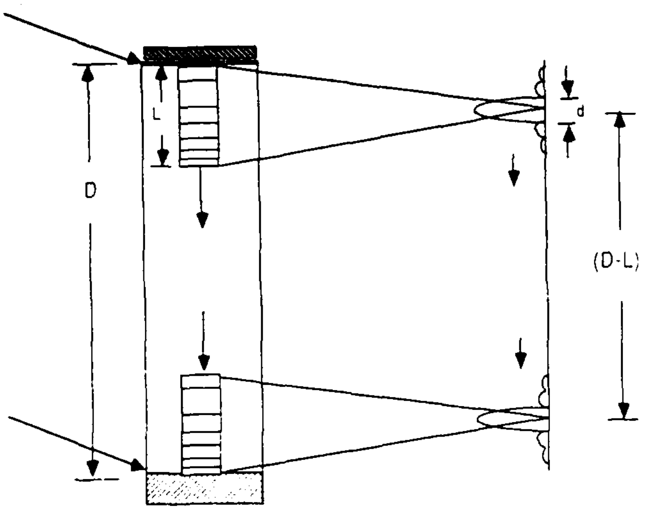

FIG. 1. Acoustic traveling wave lens schematic.

To get an approximation of the resolution of this device, consider Fig. 1. The diffraction-limited spot width d for a lens with uniformly illuminated square aperture of length L is given by

$$d = 2\lambda f_x / L,$$

where f_x is the lens focal length and λ is the vacuum wavelength of the light. The distance d is measured between the first zeros on either side of the central maximum in the diffraction pattern. A chirp lens of duration t_c, traveling in a medium with acoustic velocity v, will have a length

$$L = vt_c.$$

Its focal length can be approximated by[6]

$$f_x = v^2/(\lambda \Delta f/\Delta t),$$

where $\Delta f/\Delta t$ is the frequency chirp rate. Combining these two equations and noting that the chirp rate is $\Delta f/tc$,

$$d = \frac{2\lambda}{vt_c} \cdot \frac{v^2}{(\lambda \Delta f/t_c)} = 2v/\Delta f.$$

Typically Rayleigh's criterion is invoked to determine when adjacent spots are "just resolvable". In this case the peak of one spot is aligned with the first zero of the adjacent spot (i.e., their separation is d/2). If this criterion is accepted, the total number of spots is found by dividing the length of the active line,

$$D\text{-}L = vt_{(active)}$$

by one-half the spot width giving

$$N = \Delta f t_{(active)}.$$

Using this method with RS-343-A active line time and N = 1280, we have

$$\Delta f = 1280/24\ \mu sec = 53.3\ MHz.$$

Thus, using the traveling chirp lens approach allows one to achieve the desired resolution using acoustic frequencies in the 50–100 MHz range, which are much better suited for flat response in TeO_2 crystals.

III. BASIC DESIGN OF THE LRS

Acousto-optic laser scanning with resolutions greater than one thousand spots per scan line has been shown previously by several workers.[5-7] However, these scanning systems operated at less than video frame rates.

The specifications for the video-rate LRS design are given in Table 1.

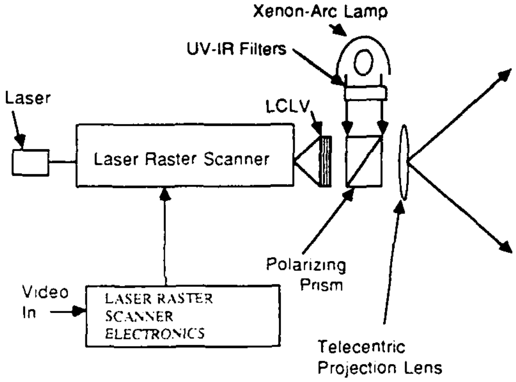

FIG. 2. Schematic diagram of laser/light-valve display prototype.

IV. MAJOR COMPONENTS

The major components or subsystems are the laser, the laser raster scanner (LRS), the LCLV, and the projection optics. Figure 2 shows a schematic of the prototype incorporating the LRS for a large-area projection-display application.

V. THE LASER

A 20-mW air-cooled argon-ion CW laser at 514.5 nm was sufficient to get the required 100 $\mu W/cm^2$ at the plane surface of the LCLV photoconductor.

Recently, the argon-ion laser was replaced with a frequency-doubled diode-pumped Nd:YAG laser, with 20-mW output at 532 nm.

VI. THE LASER RASTER SCANNER

The key optical components of the LRS are shown in Figure 3. The main components shown in Figure 3 are the following: BC1 is an acousto-optic modulator (AOM) Bragg cell, with an MTF of 0.5 at 50 MHz; BC2 is a low-resolution AO beam deflector to allow the laser beam to track the chirp (the ATWL) in BC3 which increases the optical efficiency of the scanner system; BC3 is a high-resolution AO horizontal traveling lens deflector driven by the chirp; BC4 is a high-resolution but low-speed AO deflector for the vertical scan; S is an optical stop; C is a cylindrical lens; and $\lambda/4$ is a quarter-wave plate.

VII. THE LIQUID-CRYSTAL LIGHT VALVE (LCLV

The LCLV spatially modulates the high-intensity light from an arc lamp source for projection onto a large screen. The LCLV employed is a reflective-mode device which has a cadmium sulphide photosensor on one side to read the laser write-beam and a liquid-crystal layer on the other side to modulate the high-intensity xenon read-out beam.

In operation, the LCLV photosensor layer is illuminated

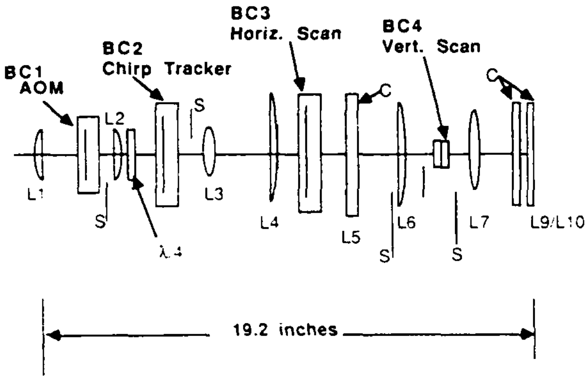

FIG. 3. Optical schematic diagram of the 1280 by 1024 resolution laser raster scanner prototype

by a write-beam from the LRS. An excitation voltage of 10 V rms at 10 kHz is applied across the LCLV. In the absence of write-beam illumination, most of the applied voltage appears across the photosensor. With illumination, the resistance of the photosensor drops and the voltage is gated to the liquid-crystal layer, thus spatially modulating the polarization of the xenon-arc beam. For detailed description and operation of the CdS-LCLV, see Refs. 1, 2, and 3.

VIII. THE PROJECTION OPTICS

The image projection system, shown in Fig. 2, consists of an arc lamp, ultraviolet and infrared filters, polarizing prism, and a telecentric projection lens. Light from the projection lamp is collimated, filtered, polarized, and directed (by the prism) to the read-side of the LCLV cell. The projection light beam then passes through the liquid-crystal layer of the LCLV and is reflected by the dielectric mirror back through the polarizing prism. The polarizing prism serves both as a polarizer and an analyzer in the transmission of optical information from the LCLV to the telecentric lens for projection onto the screen.

IX. PERFORMANCE

This prototype monochrome projection display system is capable of receiving input signals from a TV receiver, TV camera, computer data terminal, TV signal test generator, conforming to a modified 1075-line RS-343A high-resolution TV standard. Limiting resolution of more than 1300 TV lines has been measured using a TV test-generator input signal. Overall optical throughput efficiency of the laser raster scanner system is 2%.

X. SUMMARY

The goal of this work is to exploit the potential high-resolution and relatively high-speed display capabilities of the photoactivated LCLV. The use of Bragg cells with limiting resolution greater than 1300 TV lines at video rates has been demonstrated. With further improvements (mainly on the photoactivated LCLV, the Bragg cell components, and chirp drive electronics), higher resolution at TV rates can be realized. The design of a full-color projection display version of the current monochrome system is being pursued.

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REFERENCES

[1] W. P. Bleha et al., SID International Symposium Digest of Technical Papers 4, 42 (1973).
[2] J. Greenberg et al., Proceedings of the SPIE **128**, 253–266 (1977).
[3] J. Greenberg et al., IEEE Trans. Electron Dev. **ED-22**, No. 9 (1975).
[4] J. A. Trias, "Laser-Addressed Liquid Crystal Light Valve Display at Video Scan Rates," paper presented at ICALEO (International Conference on Application of Lasers and Electro-Optics), 1984.
[5] R. H. Johnson and R. M. Montgomery, "Optical Beam Deflection Using Acousto-Optic Wave Technology," SPIE **90** Acousto-Optics (1976), presented at the SPIE Symposium (August 1976).
[6] J. B. Merry and L. Bademian, "Acousto-Optic Laser Scanning," SPIE (1979), Vol. 169, Laser Printing.
[7] L. Bademian, "Acousto-Optic Laser Recording," Optical Engineering (Jan/Feb 1981), Vol. 20, No. 1.